Planning Scenarios for the Growth of Hervey Bay

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Abstract. This paper develops a methodology for investigating the question of: how can demographic (socio-economic) and land-use (physical and environmental) information models may be used to efficiently plan for future urban growth? A case study approach is undertaken using what-if planning scenarios for a rapidly growing coastal area in Australia called Hervey Bay. The town and surrounding area require careful planning of future urban growth between competing land-uses. Three potential urban growth scenarios are put forth to address this issue. The first scenario is a future trends scenario, based upon existing regional and urban trends and is examined in some detail in this paper. The other two scenarios are a 'maximise employment' scenario and 'sustainable development' scenario. Both of these scenarios are still in the developmental phase, however the framework for developing and evaluating each of the three scenarios, namely through use of a goals achievement matrix, is discussed in the concluding sections of this paper.

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Keywords. Geographic information systems, transition rules, accessibility, multiple criteria analysis, linear programming, urban and regional planning, what-if scenarios, land-use modelling.

1. INTRODUCTION

The principal aim of this paper is to develop a methodology for investigating the research question: how demographic (socio-economic) and land-use (physical and environmental) model may be used to efficiently plan for future urban growth? In order to validate the methodology a case study approach is used to test a number of what-if planning scenarios.

The methodology is formulated in terms of a number of land-use planning scenarios for the future growth of Hervey Bay, a rapidly urbanising coastal town in Australia. A framework to evaluate different planning techniques is described. This includes predictions and tactical planning for land-use change based upon: i) projections from existing trends, ii) optimising socio-economic output, and iii) decision trade-offs on a variety of factors. This paper describes the first technique and evaluates impacts as a basis for comparison on the other techniques, which will be discussed in a future paper. Despite only covering the one technique, the paper does elaborate on the framework for making land-use change predictions and evaluating planning scenarios using spatial analysis in a GIS. These spatial analysis methods include assessing land requirements, development constraints, land-use transition rules, and urban expansion based upon accessibility to services. The evaluation of planning scenarios uses a goals-achievement matrix, which brings to light how a particular planning scenario performed against local and state planning policies and objectives.

2. THE SCENARIO PLANNING APPROACH

2.1 Selecting a suitable planning approach

In order to instigate efficient land-use planning a number of planning approaches have been developed by various planning theorists, particularly in the 1960s and 1970s. Some of the core planning approaches discussed in the literature includes; the rational planning approach (Yehezkel 1963; Willer 1967; and Faludi 1973), the incrementalist approach (Lindblom 1965); the mixed scanning approach (Etzioni 1967), and the systems view approach (Chadwick 1966; and Chadwick 1978). The methodology developed in this paper is based upon the scenario planning approach as advocated by (Stillwell et al. 1999).

Scenario planning focuses upon map representations developed through the employment of analytical 'what-if' functions and spatial modelling usually undertaken in a GIS. It is closely connected to the view that planning should offer inspired visions of the future, based upon likely or preferred scenarios which are either founded upon existing planning policy or used to formulate planning policy. As stated by Stillwell et al. (1999): scenario planning can be seen as a reaction against the more procedural and instrumental orientations that characterised earlier planning approaches, as previously mentioned.

2.2 The Scenario planning methodology

The scenario planning approach applied to the case study area of Hervey Bay is shown in Figure 1. The principal planning task is to bring about the efficient planning of future urban growth in Hervey Bay. The core objectives and policies which assist in the formulation of different planning scenarios are derived from the Wide Bay 2020 Regional Growth Management Framework – RGMF (DCILGPS 1999), and the Hervey Bay Town Planning Scheme (HBCC 1996). The objectives from each of these planning documents are used later in the methodology to evaluate the efficiency of each proposed what-if planning scenario.

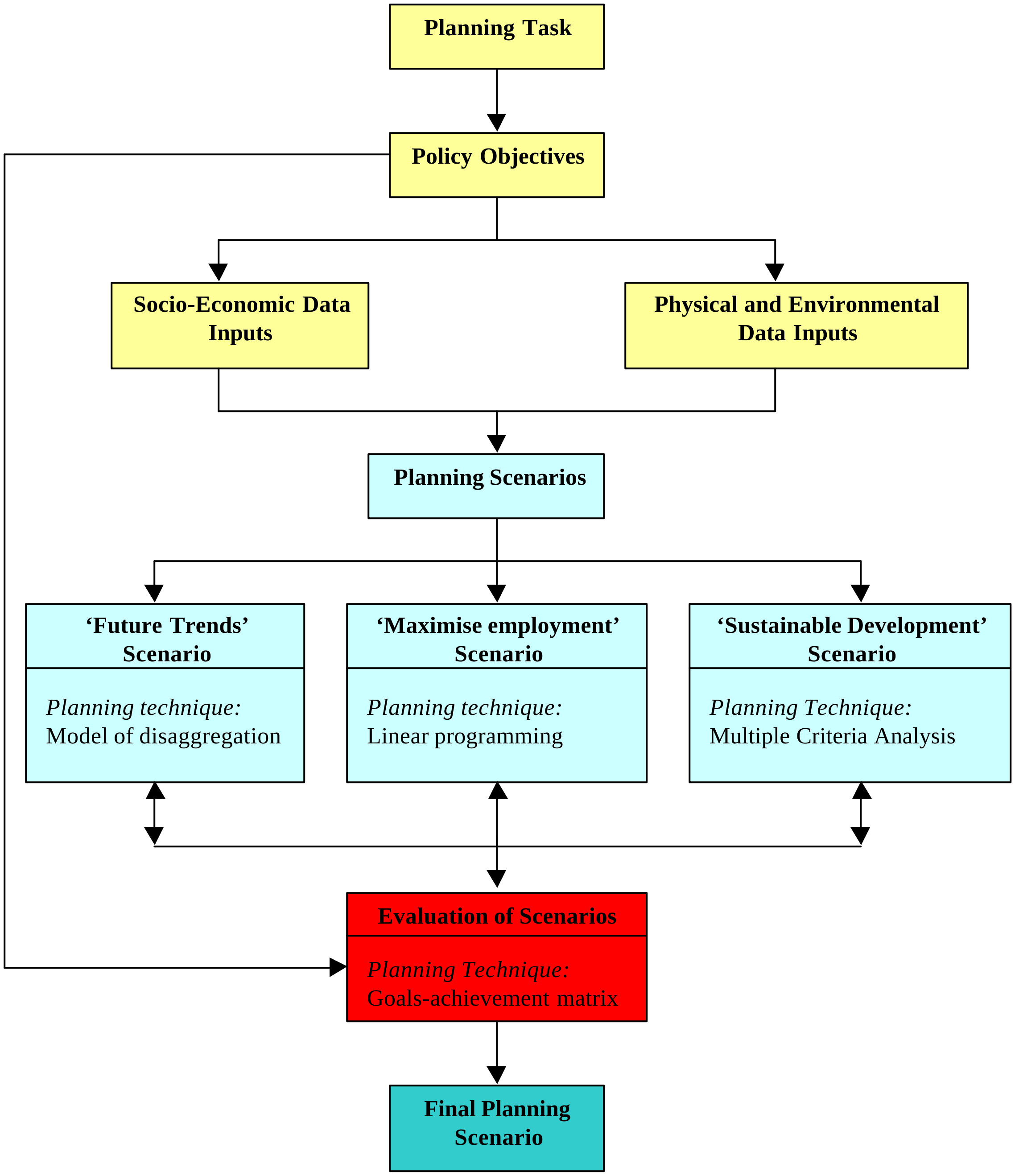

Figure 1: Scenario Planning Approach Methodology

A number of socio-economic, physical and environmental data inputs are required to drive the land-use planning scenarios. Core socio-economic data inputs include: population projections, industry employment projections, projected average household size and the projected number of dwellings. This data has been obtained from the Queensland Department of Local Government and Planning and the Australian Bureau of Statistics. It is noted that the industry employment projections have been derived using; the cohort population projection figures available up until 2021 (DLGP 2001), existing census data for 1986,1991,1996 (ABS 1997), projected industry employment trends up until 2006 (DEWRSB 2000), and a national share ratio (NSR) derived through a shift-share analysis using census data from 1986-1996 (Stimson and Davis 1999). These datasets have been integrated through linear extrapolation, standardisation and indexing techniques in order to produce projected industry employment figures (Pettit 2001).

A number of core physical and environmental data inputs are used to formulate the scenarios. The physical data inputs including: cadastral land parcels, building footprints, road, sewer, water, and land-use zoning have been obtained from the Hervey Bay City Council. The environmental data inputs including: remnant vegetation, national parks, riparian vegetated areas, coastal wetland, areas of prime agricultural land, and existing open space have been acquired from the Queensland Environmental Protection Agency, the Queensland Department of Local Government and Planning and the Hervey Bay City Council.

The next step of the methodology is to formulate possible 'what-if' land-use scenarios. Three land-use planning scenarios are formulated for Hervey Bay. The first of these makes predictions of land-use change based upon existing trends. This is essentially a 'do-nothing' scenario that takes a business as usual approach based upon existing regional and urban trends. The future trends scenario is developed using a model of disaggregation involving two steps: i) disaggregating data on socio-economic trends to predict future land-use requirements, and ii) forecasting patterns of change using land-use transition rules and accessibility indices. This scenario for Hervey Bay is examined in further detail in the ensuing sections of this paper.

The second scenario (to be described in a future paper) focuses upon maximising employment opportunities within Hervey Bay. The main objective of the scenario is to reduce unemployment through maximising the most labour-intensive organisation of existing and future land-uses. The scenario utilises linear programming to maximise the objective, and minimise possible constraints which include, ecological, technical, and financial considerations. It is envisaged that the formulation of the 'maximise employment' scenario will be based upon the technique put forth by Chuvieco (1993) which integrates linear programming and GIS for land-use modelling.

The third scenario (to be described in a future paper) focuses upon the development of a 'sustainable development' scenario. This scenario takes into account areas of both environmental and economic significance and allows trade-offs to occur between these sometimes conflicting areas. Multiple Criteria Analysis (MCA) is a suitable technique which allows decision-makers to assign various weightings of importance to different land-use factors and examine the results. There are a number of planning support systems (PSS) that enable planners and decision-makers to formulate MCA based land-use scenarios including: the spatial understanding and decision support system (SUDSS) (Jankowski and Richard 1994); the 'What-if?' collaborative planning support system (Klosterman 1999); the IDRISI decision support module (Eastman et al. 1995) the MCE Planning Arcview extension (Pettit 1999; Pettit and Pullar 1999); and the ModelBuilder Arcview GIS extension (ESRI 2000). After reviewing each of these systems it is envisaged that the formulation of the 'sustainable development' scenario for Hervey Bay will be implemented using the What-if? PSS in collaboration with the Wide Bay202 project team and the Hervey Bay City Council planning division.

The evaluation of each of the three land-use scenarios is undertaken using the core objectives as outlined in the Wide Bay2020 RGMF and the Hervey Bay Town Planning Scheme. These objectives are used in evaluating the efficiency of each proposed land-use scenario. The process of evaluation is considered iterative in that the results found through preliminary evaluation of the scenarios can lead to the re-working of a scenario. The decision to use the goals-achievement matrix (GAM) evaluation technique was done so after the review of a number of available techniques including: cost benefit analysis (CBA); planning balance sheets (PBS); and goal-achievement matrices (GAM). The goals-achievement matrix was developed by Hill (1966) to overcome the lack of reference to community objectives by the planning balance sheet (Parkin 1993). It was also a reaction against the limitations of the CBA technique, namely that with CBA all costs and benefits are expressed explicitly in monetary terms, it fails to incorporate intangible items in the actual calculations of a study area, and has the inability to handle equity considerations (Lichfield et al. 1975).

The end result of the scenario planning approach is the formulation of a final plan, to be implemented and reviewed accordingly.

3. A FUTURE TRENDS PLANNING SCENARIO FOR HERVEY BAY

3.1 Description of Hervey Bay

The Shire of Hervey Bay is situated within the Wide Bay-Burnett region along the east coast of Australia in the State of Queensland and occupies an area of approximately 2,340 square kilometres – see Figure 2. Hervey Bay includes North Fraser Island (World Heritage area) and it neighbouring islands, which account for nearly half of the shire's total land area (1,010 square kilometres).

Urban settlement in the Hervey Bay area began in the 1870s when residents and businesspersons from Maryborough started to buy land along the shores of Hervey Bay, building holiday homes, hotels and guest houses (Beer et al. 1994). The area developed an economy on agriculture (sugar cane) and tourism. Hervey Bay's attractions as a tourist centre increased with the World Heritage listing of Fraser Island and the promotion of whale watching (Beer et al. 1994). In 1976 Hervey Bay was created as a separate shire, with the status of a town in 1977, and a city in 1984 (Beer et al. 1994). Today the economy of Hervey Bay is dependant upon the tourism industry and settlement driven by retirees. Despite having strong population growth, the shire retains a dogmatically high unemployment rate close to 20% (Stimson and Davis 1999).

The planning issues for Hervey Bay are to support the growth of the area and to provide a balanced socio-economic climate. Future development that protects the environmental quality of the area is consistent with the tourism industry and also desirable from a sustainable development perspective. The framework developed to evaluate planning techniques and future growth scenarios are sensitive to environmental issues and costs of urban expansion. The first of these is explored in this section. The next section evaluates this scenario in terms of strategic goals of the region.

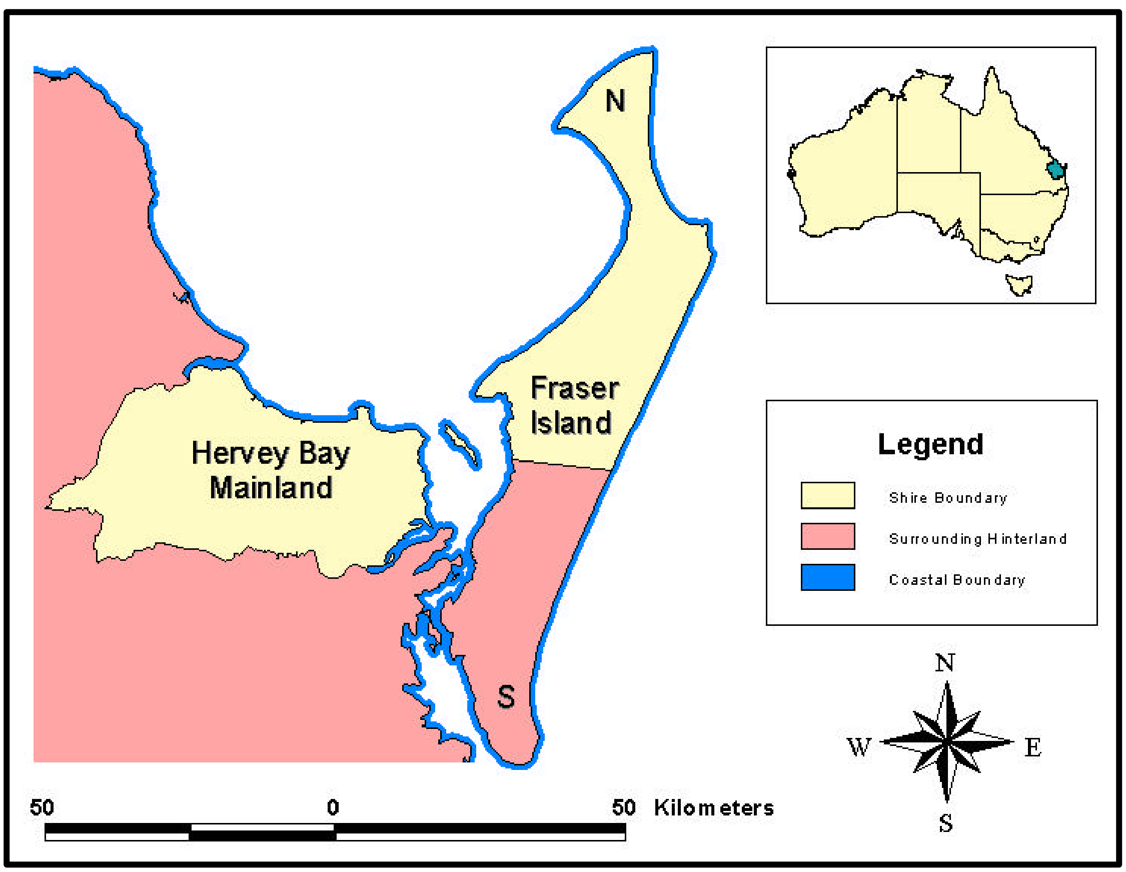

Figure 2: Shire of Hervey Bay Locality Diagram

3.2 Model of Disaggregation Technique

A regional analysis shows that Hervey Bay will grow significantly over the next twenty years (Pettit 2001). The patterns of land-use change and their impacts are of interest to planners. We explore different planning scenarios using a number of planning techniques. The first of these is to develop a plausible scenario based upon predictions of future expansion from existing trends. Regional predictions of population and employment growth by industry sector provide the main drivers of change which we wish to relate to land-use change using a model of disaggregation. The model involves two steps:

1. *land-use requirements analysis* to predict the future demand of land required for particular land-uses,
2. *land-use allocation model* that uses transition rules and spatial analysis to predict the pattern of land-use change.

Previous usage of this technique includes work carried by Peckol and Erickson (2000) in their analysis of industrial land supply and demand in the Central Puget Sound Region of Washington. An adaptation of some of the underlying concepts and transition rules used by Peckol and Erickson (2000) in establishing the demand for commercial and industrial land has been incorporated in the future trends scenario.

3.3 Land-use Requirement Analysis

Projections for regional population and employment growth are the main inputs to determining future land-use requirements. These regional figures need to be disaggregated and related to land-uses. We parameterise the demand for land in terms of population-employment and existing land usage, and then extrapolate this to future demands. The formulation for projected land required for commercial and industrial purposes is shown in Figure 3. Regional data used in this part of the model includes projected employment growth figures by industry sector. Land parcel and building footprint data provide important disaggregated inputs in the formulation of the commercial and industry land formulation. A GIS is used to calculate the average coverage ratio for each of the industrial and commercial land-use categories. Combined with the industry sector growth figure components, the total additional land required for industrial and commercial land-use has thus been determined – See Figure 5.

The component of the model which deals with the number of additional dwelling units required to accommodate the predicted increase in population requires regional datasets including; population projections, household projections, and average household size. Disaggregated data required in calculating additional residential land is based upon average residential land parcel size. The formulation for projected land required for the different residential land-use categories (medium density, low density, park, and rural) are shown in Figure 4.

Land needed = (employment growth) $\times$ (building m^2 per employee) $\div$ (coverage ratio)

where
employment growth = adjusted change in employment
m^2 per employee = total m^2 $\div$ total employment
coverage ratio = building footprint $\div$ parcel size

Figure 3: Projected requirements for commercial and industrial land

Land needed = average parcel size (m^2) $\times$ number of new dwelling

where
av. parcel size = area of existing residential land $\div$ number of land parcels
no. of new dwellings = increase in dwellings $\times$ avg. dwelling occupancy rate
no. of dwelling units $\approx$ number of households
dwelling occupancy $\approx$ household size

Figure 4. Projected requirements for residential land

Land-use	Existing Land (m2) 2001	Additional Land (m2) 2021	Total Land Required (m2) 2001-2021	Increase 2001-2021
Business Commercial	3,499,764	604,171	4103935.476	17.3%
Light Industry	374,335	147,531	521865.6552	39.4%
General Industry	2,068,459	1,011,258	3079716.436	48.9%
Medium Density Residential	1,006,253	757,132	1763385.533	75.2%
Low Density Residential	14,251,528	12,112,731	26364258.24	85.0%
Park Residential	3,841,212	3,262,677	7103888.856	84.9%
Rural Residential	9,103,411	7,739,839	16843249.68	85.0%
Conservation	1,037,520,382	-	-	-
Vacant	25,335,598	-	-	-
Total	1,097,000,940	25,635,339	1,122,636,279	-

Figure 5. Land-use Requirements

The final land-use requirements established through projected land-use requirements are shown in Figure 5. These results show that the additional land required for all residential land-use categories is expected to increase around 75-85%. Land required for business and commercial activities is expected to increase by 17.3%, whilst the land required for both light and general industry is expected to increase between about 40-50%. The results from the land-use requirement analysis, (specifically the results contained in column 3 – additional land use requirements), are used as data inputs into the next part of the model which determines the most suitable allocation for each land-use.

3.4 Land-use Allocation Model

To decide the most suitable allocation of the projected land demand with respect to land supply in Hervey Bay up until 2021, an accessibility index and land transition rules using a land-use/compatibility matrix have been employed. Accessibility is a widely used spatial analytic measure defined as the relative 'nearness' of one locality to another and has been extensively used in a wide range of land-use and transportation planning studies (Bell et al. 2000; Jiang et al. 1999; and Guitierrez et al. 1998).

A simplistic accessibility index has been formulated for the future trends scenario in Hervey Bay to assist in deciding which land parcel to assign to a particular land-use. Accessibility is measured using three parameters: distance to the CBD, distance to the harbour, and distance to major roads (arterial and sub-arterial). The accessibility index has been formulated within a GIS, using programs to calculate distances from each developable land parcel to each of the three attractors using the equation expressed below:

$$Ac_{ij,ik,il} = w_j.\sum_{ij} R_{ij} + w_k.\sum_{ik} C_{ik} + w_l.\sum_{il} H_{il}$$
$$= w_j.(\sum_{ij}\frac{1}{d_{ij}}) + w_k.(\sum_{ik}\frac{1}{d_{ik}}) + w_l.(\sum_{il}\frac{1}{d_{il}})$$

Where Ac = accessibility index; i = available land parcel; j = major road; k = Central Business District; l = Harbour; w = weighting; R = accessibility to major road; C = accessibility to CBD; H = accessibility to Harbour; d = distance.

Another Avenue script has been written to allocate future land in Hervey Bay for each land-use by specifying for each land-use the following input parameters: the total required land; the minimum land parcel size (HBCC 1996); a ranking of importance for each land-use, and a proximity restriction (i.e. outer limit for which a particular land-use could be located from similar existing development). The associated parameters entered into the land-use model for the Hervey Bay future trends scenario are specified below in Figure 6.

Land-use	Ranking	Required Land (m^2)	Minimum Parcel Size (m^2)	Proximity Restriction (m)
Business / Commercial	1	604,171	300	500
Light Industry	2	147,531	1800	500
General Industry	3	1,011,258	4000	500
Medium Residential	4	757,132	600	-
Low Residential	5	12,112,731	800	-
Park Residential	6	3,262,677	2000	-
Rural Residential	7	7,739,839	20,000	-

Figure 6: Land-use allocation parameters

The final parameter incorporated into the allocation model was the land-use / zoning compatibility matrix – see Figure 7. The land use / zoning compatibility matrix allows us to two perform two tasks. Firstly, as the future trends scenario is based upon existing land-use trends and as these trends are subject to local planning instruments, then the zoning plan is used to assist in the allocation of future land. Secondly, we can use the existing zoning data layer to measure if sufficient land for each land-use is available within the present zoning scheme. Using the overlay functionality from a GIS the spatial data layer defining the existing zoning strategy for Hervey Bay is overlayed with the land parcel data layer, thus assigning a specific zoning attribute to each of the 24,000 land parcels located within the Shire. The land-use allocation script then consults the matrix of compatible land-use when deciding upon suitable land-use parcels to be allocated for urban future development.

3.5 Scenario Results

The principal result obtained from running the model is a number of spatial land-use allocation data layers. These spatial layers can be viewed in a GIS and cross-examined with other spatial data layers; associated attributes can be analysed; and a final land-use allocation map can be generated depicting the future trends scenario, as shown in Figure 8. Preliminary analysis of urban growth scenario for Hervey Bay reveals that the existing strategic zoning boundaries are sufficient for most land-uses. However, in the case of light industry a portion of the allocated land has been drawn from land outside the existing zoning scheme using the land most suitability as indicated by the accessibility index.

	Land-use						
Zoning	Commercial	Light Ind	General Ind	Med Res	Low Res	Park Res	Rural Res
Aerodrome		X	X				
Active Open Space							
Environmental Open Space							
Holiday Village	X			X	X	X	
Industrial		X	X				
Park Residential					X	X	
Quarry			X				
Urban Residential	X			X	X		
Village	X			X	X	X	
Waste Treatment Site							
No Zoning							X

Figure 7. Land-use / Zoning Compatibility Matrix

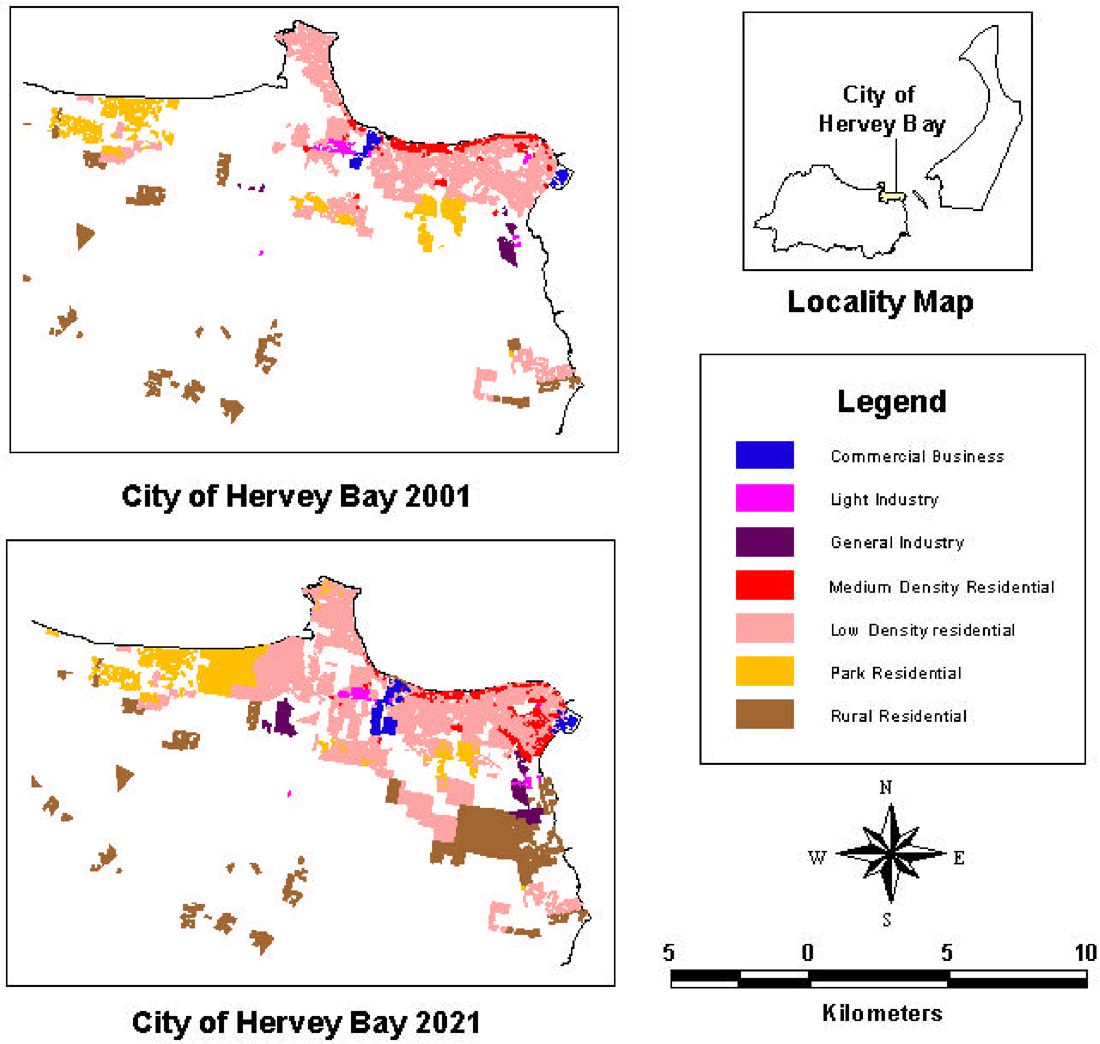

Figure 8: Future Trend for Urban Growth – City of Hervey Bay 2021

4. EVALUATION OF THE FUTURE TRENDS PLANNING SCENARIO

The efficiency of the future trends scenario is evaluated based upon a number of criteria, which are derived from key policy objectives outlined in the Wide Bay 2020 RGMF and the Hervey Bay Town Planning Scheme. Ultimately when all three scenarios have been developed, each will be assigned appropriate value weights for each of the objectives so that a comparative analysis can be undertaken within a GAM as indicated in Figure 9.

So far a number of criteria have been formulated using spatial infrastructure and environmental data layers within GIS. These criteria are indicative of some of the core objectives outlined in the Wide Bay 2020 RGMF and/or the Hervey Bay Town Planning Scheme. Infrastructure based criteria used to evaluate the scenario include; land serviced by an existing road network; land within close proximity of existing water mains; and land in close proximity to existing sewer mains. The evaluation of each of these infrastructure criteria has been undertaken using the '*intersect*' and '*within distance of*' spatial query functionality available within GIS.

Source	Objectives	Scenario 1 'Future Trends'	Scenario 2 'Maximise Employment'	Scenario 3 'Sustainable Development'
Wide Bay 2020 RGMF	1			
	2			
	3			
	4			
	5			
Hervey Bay Town Plan	6			
	7			
	8			
	9			
	10			

Figure 9: Goals-Achievement Matrix for Evaluation of Planning Scenarios

Similarly the evaluation of the environment based criteria has been undertaken in GIS using the following available or created data layers: prime agricultural land; significant remnant vegetation; national parks; coastal wetlands; riparian vegetation; and existing open space. A number of spatial operations including *buffering* and *union* have been utilised within GIS to create the coastal wetlands and riparian vegetation data layers, as defined by the Queensland Environment Protection Agency (EPA 2000). The results for each of the criteria with respect to the land-use categories has been calculated in Figure 10 as a percentage of land which is either not sufficiently serviced by existing infrastructure or which negatively impacts upon land considered environmentally significant.

Examination of the GAM results show that the efficiency of future trends for urban growth scenario are positive for most of the criteria. However, there is a significant disparity with respect to water infrastructure and sewer infrastructure, where between 30-45% of proposed urban growth will not be sufficiently serviced by the respective infrastructure networks. Specifically, with respect to the water infrastructure criteria, proposed general industry, park residential and rural residential land-uses do not measure well. When analysing the breakdown of land-use performance with respect to the sewer infrastructure criteria it can be seen that significant additional infrastructure will be needed to service projected general industry, low residential, and park residential development. Another finding revealed through the GAM results shows that 50% of the projected medium residential development conflicts with the existing open space system. Through the evaluation of the scenario using the GAM a number of potential land-use allocation conflicts are brought to light. These problems can then be addressed through appropriate planning and decision-making bodies through the formulation and implementation of suitable policies and plans.

	Land-use							
Criteria	Commercial	Light Ind	General Ind	Med Res	Low Res	Park Res	Rural Res	Average (%)
Road Infrastructure	2	16	0	0	4	0	1	3
Water Infrastructure	5	16	34	11	15	45	63	37
Sewer infrastructure	2	16	68	10	27	76	0	43
Prime Agriculture	0	0	0	0	0	0	10	1
Remnant Vegetation	0	0	0	0	2	0	11	2
National Park	0	0	0	0	0	0	0	0
Coastal Wetlands	3	0	0	12	8	4	3	4
Riparian Vegetation	5	1	1	1	2	1	0	2
Open Space	5	15	0	50	9	1	2	12

Figure 10: Goals-Achievement Matrix for Scenario

5. CONCLUSIONS

This paper has focused upon the development of a methodology for investigating how demographic (socio-economic) and land-use (physical and environmental) information models be used to efficiently plan for future urban growth? So far a future trends scenario has been formulated for Hervey Bay, based upon a model of disaggregation which used transition rules, an accessibility index, and GIS spatial processing functionality. Preliminary evaluation of the scenario has been undertaken using a GAM planning technique.

Further work to be undertaken will concentrate on the calibration of the model of disaggregation technique, and the development of the 'maximise employment' and 'sustainable development' scenarios. Once the final two scenarios have been developed a comparative analysis will be undertaken to investigate the strengths and weaknesses of all three scenario and the efficiency of the planning techniques employed to formulate each scenario.

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